Computer Graphics and Animation

Date: Wednesday 19th January 2011
Time: 09:45 - 11:45

Please answer any THREE Questions from the FIVE questions provided

Each question is worth 20 marks

For full marks your answers should be concise as well as accurate. Marks will be awarded for reasoning and method as well as being correct.

This is a CLOSED book examination

The use of electronic calculators is NOT permitted
1.
a) i) Disney animators introduced twelve principles of traditional animation that can also be applied to computer animation. Two of these principles are slow-in/slow-out and squash-and-stretch. Describe these two principles and how an animator can use these principles to show different weights of a character or object.

(4 marks)

ii) When animating human characters the animator will often use *Moving Holds*. Describe this technique, explaining why it should be used and give an example of its use.

(3 marks)

iii) Describe what is meant by Computer Assisted Animation and the type of animation it is used to create. Give an advantage that 3D Computer Animation has over Computer Assisted Animation.

(3 marks)

b) i) A key principle of the RenderMan architecture introduced by Pixar is the separation of the modelling domain from the rendering domain. Explain why this is a good approach for a scene description language.

(2 marks)

ii) RenderMan renderers are often described as Micropolygon renderers. Explain what this means and give an advantage and disadvantage of this type of rendering methodology.

(3 marks)

iii) Discuss how the current features in GPU hardware and shading languages could make micropolygon rendering the continued choice for rendering.

(5 marks)

**Total: 20 marks**
2.
a) i) Euler Angles is one method of representing rotation in a computer animation system. Describe the Euler Angles representation. (2 marks)

ii) Explain the term *gimbal lock* and why this is a disadvantage of the Euler Angles representation. (2 marks)

iii) Equation 1 gives the rotation matrix \( M_R \) for Euler Angles rotation about the x, y, and z axes, where \( \theta, \phi \) and \( \gamma \) represent the rotation angles about the x, y and z axes respectively; \( c_\theta \) represents \( \cos(\theta) \); \( s_\gamma \) represents \( \sin(\gamma) \) and so on.

\[
M_R = \begin{bmatrix}
  c_\phi c_\gamma & c_\gamma s_\theta s_\phi - c_\theta s_\gamma & c_\phi s_\gamma + s_\theta s_\phi & 0 \\
  -s_\phi c_\gamma & c_\gamma s_\theta s_\phi + c_\theta s_\gamma & c_\phi s_\gamma - s_\theta s_\phi & 0 \\
  -s_\gamma & c_\theta s_\gamma & c_\phi c_\gamma & 0 \\
  0 & 0 & 0 & 1
\end{bmatrix} \tag{Eq 1}
\]

If the animator rotates an object through 90 degrees on the y axis show that this leads to gimbal lock. Hint: it is not necessary to expand all the terms in the matrix if they do not reduce to simple constants. (5 marks)

b) i) Quaternions are an alternative representation of rotation used in computer animation. Describe this representation of rotation, showing how a rotation through an angle \( \theta \) about an axis \( (x,y,z) \) is represented in quaternion form. (3 marks)

ii) Given a point \( P \) on an object, give the equation that rotates the point using a quaternion \( q \), explaining the terms in the equation. (2 marks)

iii) Explain why, when interpolating between two quaternions \( q_1 \) and \( q_2 \), it may be more desirable to interpolate between quaternions \( q_1 \) and \( -q_2 \). Include in your answer a method of choosing between using \( q_2 \) and \( -q_2 \). (5 marks)

iv) Spherical linear interpolation is often used to perform the interpolation between \( q_1 \) and \( q_2 \) (or \( -q_2 \)). Give one problem with this method. (1 mark)

**Total: 20 marks**
3. 

a) 

i) A computer animation system allows the animator to animate hierarchical models, such as human figures, using forward kinematics (FK). How does the animator use this method? 

(1 mark)

ii) Why is a computer animation system that uses a hierarchical representation of a character to be animated helpful to the animator? 

(2 marks)

Figure 1 shows part of a simple human character to be animated. $T_0$ is the translation to position the root object Link$_0$ in the world coordinate system. The angles $\theta_i$ are the local joint angles.

![Hierarchical Model](image)

iii) Draw a tree diagram that represents how a computer animation system would store this object internally. Your diagram should show which transforms are stored in the arcs in such a representation. 

(5 marks)

iv) To render the geometry data held in each link the computer animation system applies transformations to each vertex of the geometry. Give the transformation that would be applied to a vertex on the object held in Link$_{1.1}$. 

(2 marks)

b) 

i) Briefly describe the Inverse Kinematic (IK) method of animating a model in a computer animation system. 

(1 mark)

ii) Describe the IK algorithm, including in your answer the information that is related by the Jacobian matrix. 

(5 marks)

(Question 3 continues on the following page)
iii) You have been asked to develop a tool to assist an animator in animating dinosaurs and other creatures performing walking motion. Your software has access to a hierarchical representation of the creature. You also have access to a function which will perform inverse kinematics. Describe how your tool will animate the creature. Specify how you apply the inverse kinematics function and what you supply as input to this function. You should mention any parameters that you wish the animator to supply and how you will use these parameters. (4 marks)

Total: 20 marks

4. a) i) Describe the three key rules for the flocking of boids in an animation system, and state their order of precedence. (4 marks)

ii) For each key rule above, illustrate with a simple diagram how the rule can be implemented, assuming a spherical zone of sensitivity. (4 marks)

ii) Discuss why these rules are often not sufficient for an animator when using a flocking system and how the animator can overcome this problem. (2 marks)

b) i) Briefly describe the following three extra flocking rules and give a reason why they would be of benefit to an animator if added to a flocking system:
   - Migration rule
   - Floor Avoidance rule
   - Building Avoidance rule

   (4 marks)

ii) Define and discuss the complexity of the flocking algorithm as the number of boids, N, increases. Describe an alternative scheme that can be used when N becomes very large. (3 marks)

c) An animator wishes to model flying carnivores and herbivores, where carnivores may attack herbivores, using a combined flocking system. Explain how the rules can be adjusted for these two types of boids while maintaining the same underlying system. (3 marks)

Total: 20 marks

[PTO]
5.

a) i) A computer animation system uses parametric interpolation to create motion graphs that control the animation of objects. Describe motion graphs and give a reason why parametric interpolation is used (you do not need to write out interpolation formulae).

(5 marks)

ii) State a characteristic of the motion created when linear and Bezier interpolation schemes are used.

(1 mark)

iii) Bezier curves do not have arc length parameterization. Explain what this means and describe the problem it creates in a computer animation system.

(4 marks)

b) i) Describe what is meant by the term particle system and give two examples of the effects they are used to create in computer animation.

(3 marks)

ii) Give four items of information stored with each particle in a particle system.

(2 marks)

iii) Give an algorithm for a particle system, describing the lifetime of a particle and how it can be rendered if the particle is to represent a spark.

(5 marks)

Total: 20 marks

END OF EXAMINATION